Flow and Suspended Sediment Events in the Near-Coastal Zone off Corpus Christi, Texas

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LONG-TERM GOALS

Our long-term goal is to gain some insight into the physics of short-term fluctuations of flow and property distributions in a low tidal energy, coastal zone dominated by wave and currents and assess our ability to model them.

OBJECTIVES

Each inner continental shelf region has an interesting combination of current, wave and sediment regimes. White et al. (1983) characterize the surface sediments off Corpus Christi, Texas, as dominantly very fine sand in the nearshore zone, from the shoreface out 6-8 km, transitioning to mud (silt-clay) farther offshore. The pattern does not vary substantially alongshore. They indicate that the main processes responsible for the shelf sedimentation in this region are (1) suspension and redistribution of preexisting shelf sediments during storms and (2) transportation of suspended sediment from the adjacent bay-lagoon system. Snedden et al (1988) found that the combined bottom currents and wave-orbital motion associated with storm events were the means by which fine sands could be transported across the shelf and deposited in thin (< 10 cm) beds (Berryhill and Trippet 1981). In the low tidal energy region of the Gulf of Mexico both stochastic and episodic events frequently dominate, driven by atmospheric fronts (including the forcing mechanisms of direct wind stress, surface waves, and heating/cooling), freshwater discharges, stratification, and seasonal upwelling. A strong focus of this proposal is the interaction of these processes and their role in the dynamics of flow and sediment distributions.

The specific objectives of this study are:

- To develop additional software that assimilates the existing data flows from our two offshore real-time sites for automatic real-time calculation of total suspended sediment concentration profiles from the acoustic backscatter profiles provided by the ADCPs. The algorithms will be updated as additional calibration data become available from each survey cruise to the offshore sites.

- To conduct calibration survey cruises to bay and offshore sites to collect the necessary data for calibration of the ABS profiles of the ADCPs.

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14. ABSTRACT
Our long-term goal is to gain some insight into the physics of short-term fluctuations of flow and property distributions in a low tidal energy, coastal zone dominated by wave and currents and assess our ability to model them.

15. SUBJECT TERMS

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▪ To use a suspended sediment transport model (developed in our labs) that explicitly describes sediment aggregation effects using population balance kinetics to study the sediment settling velocity (a function of the hydrodynamic effects, which vary with current).

APPROACH

This study leverages components of the existing real-time observation system (Figure 1) operated by Texas A&M University-Corpus Christi (TAMU-CC) (Bonner et al. in press). Components include: a real-time observation station established 17 nmi offshore Corpus Christi in 30-m water depth that provides wind velocity, barometric pressure, air and water temperature, directional wave data, and vertical profiles of acoustic backscatter (ABS) intensity and horizontal current velocity from a bottom-mounted RDI Workhorse ADCP (see dnr.cbi.tamucc.edu/overview/098); an identically instrumented platform for the Port of Corpus Christi Real-time-Navigation System at site about 5.5 nmi offshore in 18-m depth; and the NOS tide station at Bob Hall Pier.

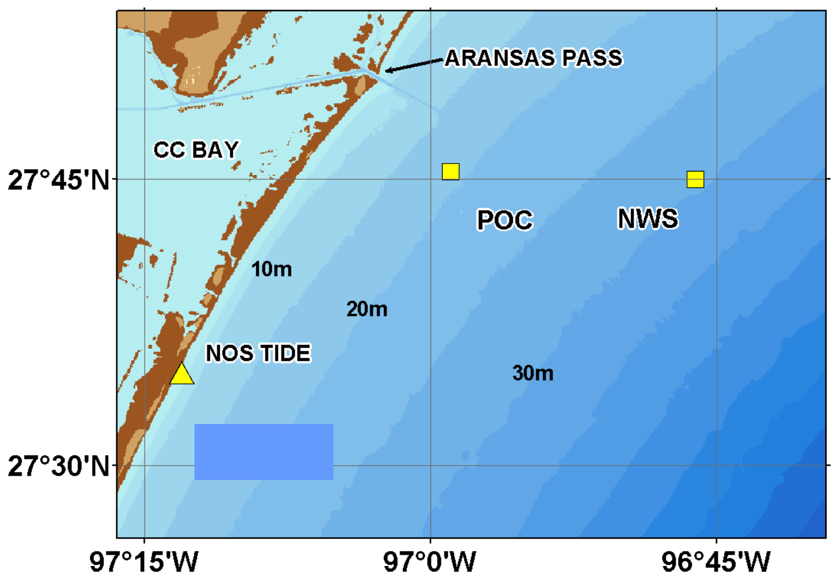

Figure 1. Map of Texas coast off Corpus Christi area. POC and NWS are platforms about 5 and 17 nmi offshore, respectively, instrumented with met sensors and a bottom-mounted ADCP. NOS TIDE is a long-term NOS tide station. All are real-time sites.

The theory and procedures for deriving suspended solids concentrations from ADCP relative backscatter data are becoming established and documented for both bottom-mounted (Gartner 2002; Gartner and Cheng 2001; Byrne 2001) and ship-mounted configurations (Reine et al. 2002; Land and Jones 2001; Puckette 1998). Estimation procedures require knowledge of the ADCP parameters and setup specific to an instrument, especially its calibrated received strength signal indicator (RSSI) reference level, the water's absorption coefficient as a function of salinity, temperature and pressure, and, most importantly, measurement of the total suspended sediment concentration (TSSC). The latter has typically been obtained from water samples, or from optical backscatter sensors (OBS). More recently, the optical sensor of choice for calibrating the ADCP ABS profile is a Laser *in-situ* Scattering Transmissometer (LISST) (Gartner 2002; Agrawal and Pottsmith 2000), which provides data on both

TSSC and size distribution. Further refinements in the instrument's algorithm for scattering theory will soon replace the spheres model with a model for natural grains (Agrawal and Pottsmith 2002). The LISST provides immediate results, and thus, when used in conjunction with a ship-mounted ADCP, underway profiles of ABS can be converted to TSSC if periodically profiles using a LISST and CTD are also collected. A second mode of ADCP use for TSSC profiles is the moored or bottom-mounted configuration. Gartner and Cheng (2001) point out that although optical and acoustical instruments react differently to grain size, the acoustic method provides TSSC estimates concurrent with velocity measurements, and it overcomes the problem of biofouling, a major limitation of optical instruments. Thus, Gartner and Cheng (2001) conclude that using ABS profiles from an ADCP provides reasonably accurate estimates of TSSC, but additional testing is needed to study the consistency of results. Our work will focus on the consistency through cruises to our operational sites.

Most changes in the optical properties of seawater are caused by particles suspended or settling through the water. We are documenting and studying particle distributions and dynamics through real-time observations and modeling. We will use existing models to study particle concentration and variability in response to a variety of dynamic conditions and events consistent with and supported by real-time observations. Field observations will evaluate predicted dynamics, assess modeled dynamics sensitivity to observed parameters, and evaluate assimilation of real-time data collected via the observation network. We are developing a suspended sediment transport model that explicitly describes sediment aggregation effects using population balance kinetics (Ernest et al., 1995; and Garton et al. 1995; Lee et al., 2000, 2001;). Using this approach, the sediment settling velocity is a function of the hydrodynamic effects, which vary with current. Given a time series of particle concentration measurements as given by the LISST-100, we will be able to detect changes in suspended sediment concentration and size distribution. Further, given these data inputs to the transport model, we can estimate the relative influence of resuspension and corresponding deposition in the suspended sediment transport. The offshore sites are located in a coastal region where salinity can vary substantially because of alongshore transport of upstream river discharge and local outflow from Aransas Pass during flood events. Because of the fine sediment sizes and the salinity variability, the study will also look at the potential for flocculation to be a process that should be included in any SSC model for this region.

Dr. Jim Bonner is directing this project and the modeling work of his students. Mr. Frank Kelly is supervising the data collection of the CBI staff over the project period, and Dr. Bill Schmitz is providing overview and review of the data interpretation.

WORK COMPLETED

This project was awarded January 22, 2003. Since then, ADCP profiles of current and backscatter intensity and also wave parameters from the two offshore sites have been examined and some resuts are posted http://www.cbi.tamucc.edu/ResearchProjects/CMPWaves. At a site in Corpus Christi Bay, cruises have been conducted to collect profiles of suspended sediment size distribution (LISST-100) and currents and acoustic backscatter intensity (ADCP). The purpose of the bay cruises is to develop the techniques of collecting and analyzing the data in region easily accessible by small boat (Ojo et al. in press).. The R/V Longhorn, a UNOLS vessel operated by the University of Texas Marine Science Institute is scheduled to make several offshore cruises for this study beginning October. (This vessel has been solidly booked until now.)

Since optical and acoustical instruments react differently to grain size, the equipment to process standard water and sediment are also needed. A Malvern Mastersizer-600 has been acquired from another university component for analysis of water samples of suspended sediment, and an automated shaker-sieving system has been purchased by a collaborating project for bottom sediment analysis. Given the particle size range of our study area, Our LISST-100 Type B has been returned to the manufacturer for retrofit to a Type-C, which will change the range from 1.25-250 μm to 2-500 μm.

The modeling task has completed several studies, as described below.

RESULTS

Sterling et al. (in press) determined the effects of emulsified crude oil and salinity (15 and30) on the steady state aggregate volume distributions and fractal dimensions for a range of mean velocity gradients, (G_m = 5 to 50 s^{-1}). Three-dimensional fractal dimensions (D_3) and volume distributions were determined using a procedure integrating data from an electrozone and an in-situ light scattering instrument. Two-dimensional fractal dimensions (D_2) and derived volume distributions were determined using a recently developed submersible flow cytometer equipped with a digital camera and image analysis software. The results suggest that colloidal oil and mixing shear are the more dominant factors influencing aggregate morphology in nearshore waters. Overall, the data suggests that the analysis methods provide consistent size distribution results. However, because of the shear and salinity of coastal waters, resulting aggregates are too compact to estimate their D_3 values using image analysis alone.

In a manusctipt titled "Determination Of Collision Efficiencies For Flocculent Particle Transport Models: Heterogeneous Density Systems", in preparation for submission to Environmental Science and Technology, Sterling et al. have taken a modeling approach that simulates changes in particle size distribution and density due to aggregation by extending the Smoluchowski aggregation kinetic model to particles of different density. Batch flocculation studies were conducted from clay, colloidal silica, crude oil, clay-crude oil, and silica-crude oil systems. A parameter estimation algorithm was used to estimate homogeneous collision efficiencies for single particle type systems and heterogeneous collision efficiencies for two particle type systems. Homogeneous collision efficiency values were greater for clay and for crude oil than for silica. Thus, clay and crude oil were classified as cohesive particles while silica was classified as noncohesive. Heterogeneous collision efficiencies were similar for clay-oil and silica-oil systems. Thus, crude oil increases the aggregation of noncohesive particles. Apparent first order flocculation rates were determined for oil, clay and silica using laboratory data. Apparent second order flocculation rates for oil and clay in oil-clay systems and for oil and silica in oil-silica systems were estimated using simulation data. Results suggest that clay flocculation and oil coalescence may occur on the same timescales as clay sedimentation and oil resurfacing, respectively, and that clay-oil aggregation may occur on the same timescale as sedimentation.

In another manuscript in preparation, titled "Determination Of Collision Efficiencies For Flocculent Particle Transport Models: Heterogeneous Fractal Systems", Sterling et al. find that conventional aggregation kinetic models do not describe flocculation between particles with different fractal dimensions and densities as expected in estuarine and coastal environments. They describe a modeling approach that simulates changes in particle size distribution (PSD), fractal dimension, and floc density due to aggregation. Model predictions were compared with a series of PSD data obtained from laboratory batch coagulation data collected from clay, colloidal silica, emulsified crude oil, clay-crude

oil, and silica-crude oil systems. In the parameter estimation algorithm, the minimized objective function, mean of the sum of the squares of the relative residuals (MSSRR), was a relative least squares residual rather than the typical unweighted least squares residual. The mCFS model had MSSRR values up to 15% lower than that obtained using the Euclidean model. For a given aggregate mass, reducing an aggregate's fractal dimension lowered its settling velocity. Thus, the timescale of sedimentation becomes greater than that of clay-oil aggregation.

IMPACT

The proposed study region lies just upcoast (~20 nmi) of a training area for COMINEWARCOM, NAS Corpus Christi, and Naval Station Ingleside. Because of the alongshore uniformity of sediment distributions in this region of the Texas coast, the results of this work may have relevance to Navy programs related to the nearby mine warfare exercises. Furthermore, the specific methods and techniques we will employ to obtain SSC calibration data during repeated cruises to the sites and the real-time SSC profiles estimated from the bottom-mounted ADCPs may also be useful and transferable to Navy mine warfare operations, as they would provide needed input to Navy mine reburial models and assessment ofnear-bottom visibility conditions prior to training exercises. The authors have met with Met-Ocean officers from COMINEWARCOM, NAS Corpus Christi, and Naval Station Ingleside, and discussed the potential for supplying the proposed information to them. They already freely utilize our existing real-time metocean data for this area that is provided on our website.

RELATED PROJECTS

This study is possible because it leverages on several related projects. These include:

- The PhD Pipeline Project, funded by the Texas General Land Office (TGLO), which provides funding to doctoral students to develop real-time sensing and modeling of the coastal environment with an emphasis on oil spill related research. (http://www.cbi.tamucc.edu/)

- The Wave Climate Monitoring project, funded by TGLO's Coastal Management Program, which funds development of near-shore directional wave climatology from data collected at the the real-time platform sites offshore Port Aransas (http://www.cbi.tamucc.edu/ResearchProjects/CMPWaves)

- The Coastal Inlets Study Project, funded by the U.S. Army Corps of Engineers (USACE), which provides momitorin, analysis, and GIS interpretation of hydrodynamic and sediment ransport systems for ilets on the central Texas coast. (http://www.cbi.tamucc.edu/ResearchProjects//HydroSedTransport/default.htm)

- The Texas Coastal Ocean Observation Network (TCOON), funded by TGLO, the Texas Water Development Board and the USACE.. It collects near real-time water level, wind velocity, water quality, and other environmental data from stations placed in the bays and estuaries along the Texas coast. (http://lighthouse,tamucc.edu/)

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